US009469552B2

(12) **United States Patent**
Horst et al.

(10) **Patent No.: US 9,469,552 B2**
(45) **Date of Patent: Oct. 18, 2016**

(54) **PRODUCED FLUID HEATING AND SEPARATION**

(71) Applicant: **Amcol International Corporation**, Hoffman Estates, IL (US)

(72) Inventors: **Jason Horst**, Madisonville, LA (US); **Keith Doucet**, Covington, LA (US)

(73) Assignee: **AMCOL INTERNATIONAL CORPORATION**, Hoffman Estates, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/136,004**

(22) Filed: **Apr. 22, 2016**

(65) **Prior Publication Data**

US 2016/0236946 A1 Aug. 18, 2016

Related U.S. Application Data

(62) Division of application No. 13/424,937, filed on Mar. 20, 2012, now Pat. No. 9,347,303.

(60) Provisional application No. 61/473,433, filed on Apr. 8, 2011.

(51) **Int. Cl.**

C02F 1/02	(2006.01)
E21B 43/34	(2006.01)
F02B 65/00	(2006.01)
C02F 101/32	(2006.01)
C02F 103/10	(2006.01)

(52) **U.S. Cl.**

CPC ***C02F 1/02*** (2013.01); ***E21B 43/34*** (2013.01); ***F02B 65/00*** (2013.01); *C02F 2101/325* (2013.01); *C02F 2103/10* (2013.01); *C02F 2201/001* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,506,412 A		5/1950	Chausse	
3,833,059 A		9/1974	Sisson	
4,190,205 A		2/1980	Mitchell	
4,197,712 A		4/1980	Zwick et al.	
4,372,386 A		2/1983	Rhoades et al.	
4,409,927 A		10/1983	Loesch et al.	
4,641,710 A		2/1987	Klinger	
5,192,431 A	*	3/1993	Holmes	B01F 1/0027 210/198.1
5,207,903 A	*	5/1993	Giberson	B01D 35/12 210/238

(Continued)

FOREIGN PATENT DOCUMENTS

GB 2489815 A 10/2012

OTHER PUBLICATIONS

Bostick et al., Characterization of soluble organics in produced water, Oak Ridge National Laboratory (Jan. 2002).

(Continued)

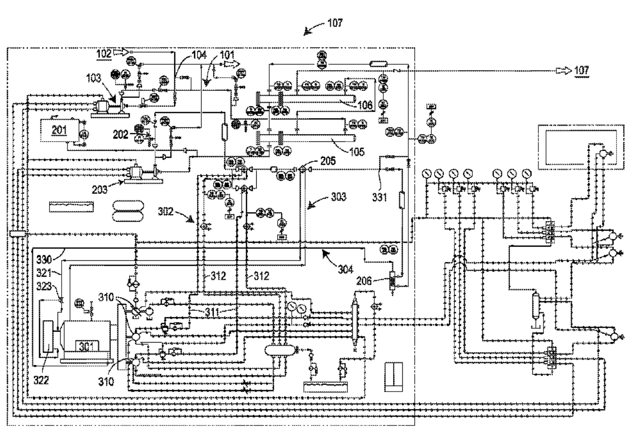
Primary Examiner — Robert James Popovics

(74) *Attorney, Agent, or Firm* — Squire Patton Boggs (US) LLP

(57) **ABSTRACT**

An apparatus and method for heating produced fluid from a well, the heating apparatus comprising a produced fluid pathway; a heat generation system comprising a diesel engine, a heated hydraulic fluid pathway, and an engine coolant pathway; and a heat transfer system disposed between the produced fluid pathway and the heat generation system to transfer thermal energy from the heat generation system to a produced fluid contained within the produced fluid pathway.

9 Claims, 11 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

5,215,454	A	6/1993	Ferramola et al.
5,335,728	A	8/1994	Strahan
5,567,318	A	10/1996	Beall
5,656,136	A	8/1997	Gayaut et al.
5,670,435	A	9/1997	Kajita
5,695,643	A	12/1997	Brandt et al.
5,922,206	A	7/1999	Darlington, Jr. et al.
5,935,444	A	8/1999	Johnson et al.
5,988,280	A	11/1999	Crawford et al.
6,032,732	A	3/2000	Yewell
6,073,695	A	6/2000	Crawford et al.
6,235,201	B1	5/2001	Smith et al.
6,358,422	B1	3/2002	Smith et al.
6,398,951	B1	6/2002	Smith et al.
6,398,966	B1	6/2002	Smith et al.
6,409,924	B1	6/2002	Johnson et al.
6,415,866	B1	7/2002	Baugh
6,749,757	B2	6/2004	Smith et al.
6,893,615	B1	5/2005	Alexander
7,297,279	B2	11/2007	Johnson et al.
7,445,761	B1	11/2008	Alexander
7,703,528	B2	4/2010	Schultz et al.
7,765,794	B2	8/2010	Alexander
8,371,251	B2	2/2013	Frick
8,534,235	B2	9/2013	Chandler
9,347,303	B2 *	5/2016	Horst et al. E21B 43/34
2011/0005757	A1	1/2011	Hebert
2012/0255916	A1 *	10/2012	Horst et al. E21B 43/34 210/774
2013/0126174	A1	5/2013	Henson et al.
2013/0200012	A1 *	8/2013	Holmes et al. B01D 29/114 210/804

OTHER PUBLICATIONS

Heat Transfer Fluid, Duratherm Heat Transfer Fluids (publicly available before Apr. 8, 2011).

Heat Transfer Fluids product sheet, Dynalene Inc., (Oct. 2008).

Home pag of website for Dynalene Inc. (Oct. 2008).

Search Report from the United Kingdom Intellectual Property Office for corresponding application No. GB1206057.0 (dated Jul. 12, 2012).

Separation & Separators—Separator Functions, downloaded from the Internet at: <http://articles.compressionjobs.com/articles/oilfield-101/1008-separation-separators-well-fluid-coalescing> (written Jan. 26, 2010, last updated Feb. 24, 2010).

* cited by examiner

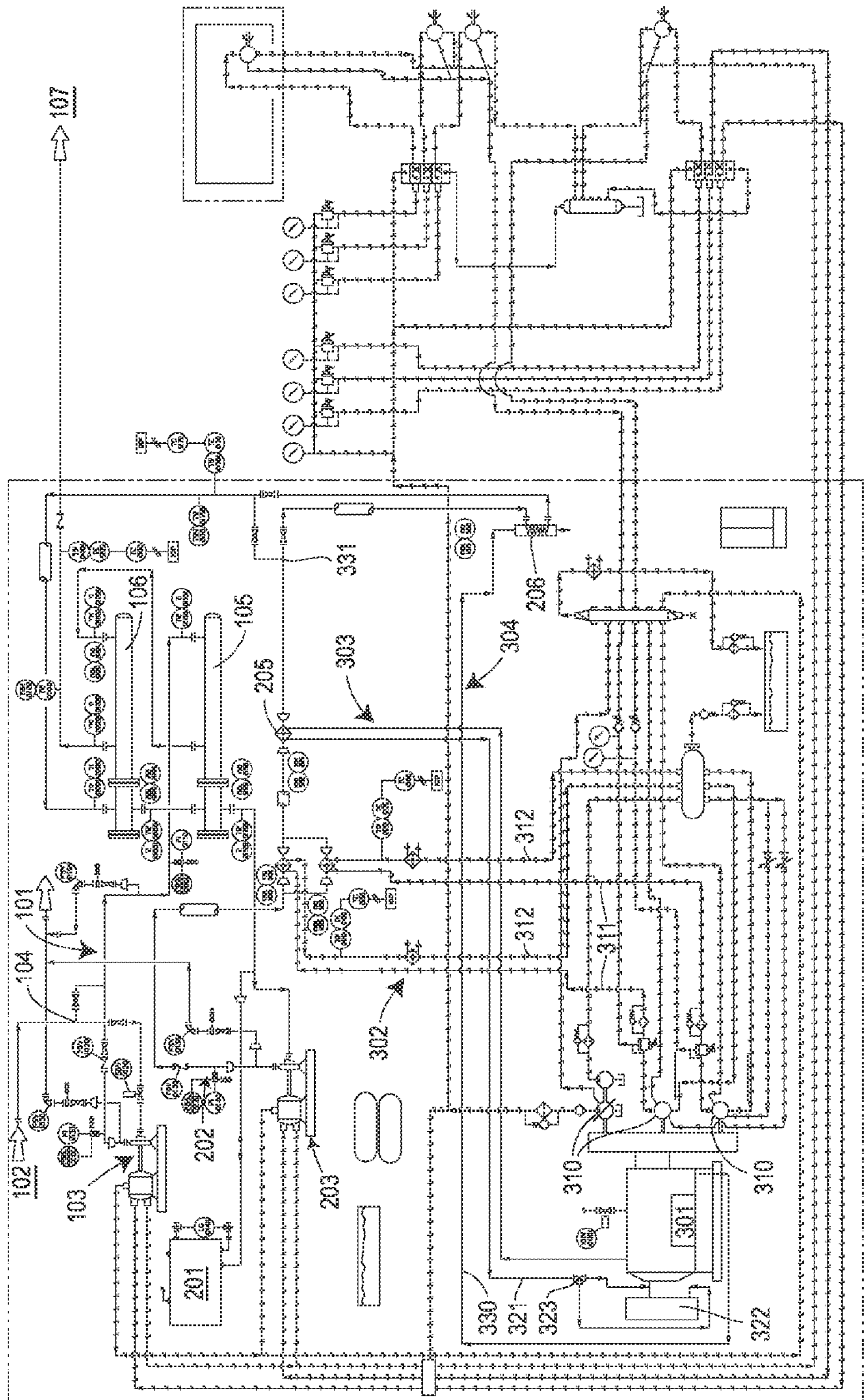

107
107
101
104
102
103
201
202
203
106
105
205
303
331
206
304
302
312
312
311
310
310
301
330
321
323
322

FIG. 1

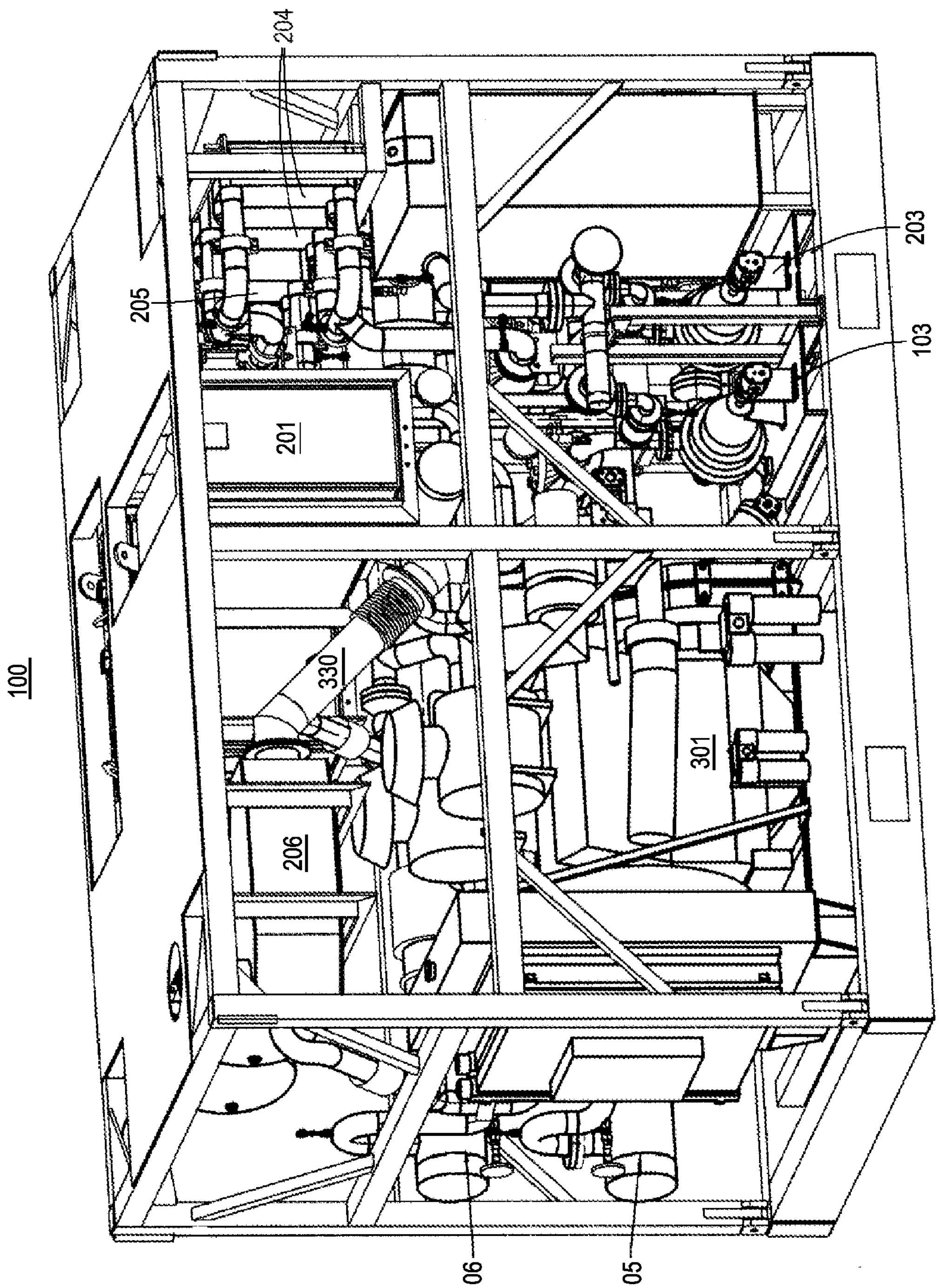


FIG. 2

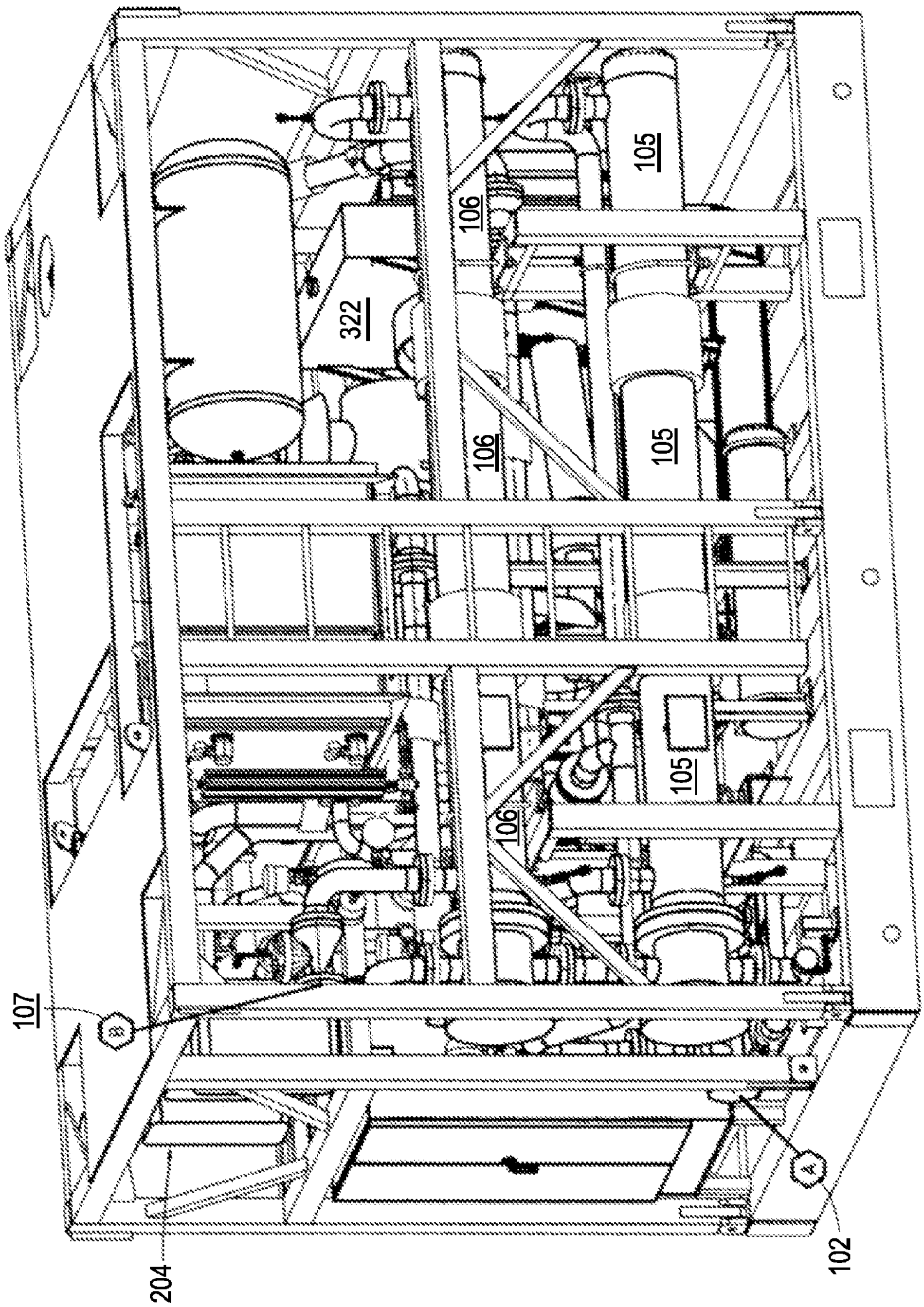


FIG. 3

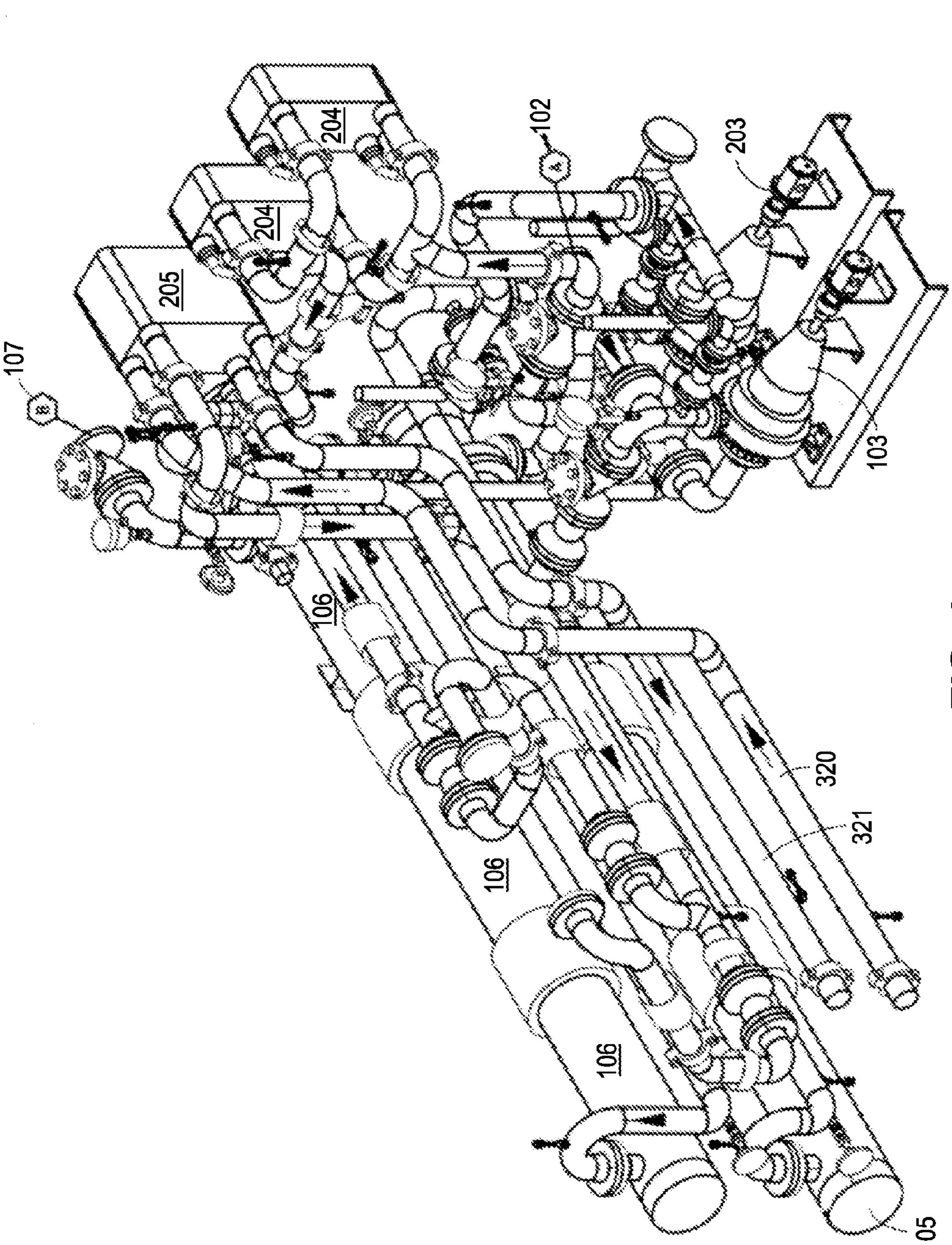


FIG. 4

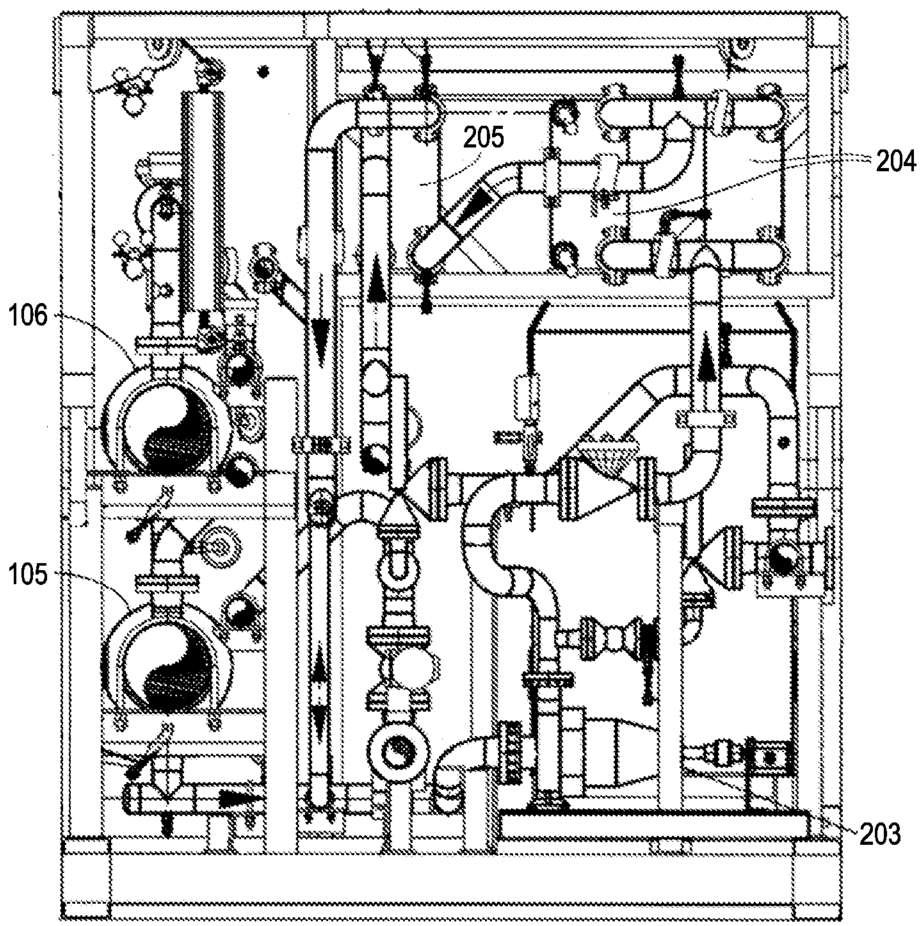


FIG. 5

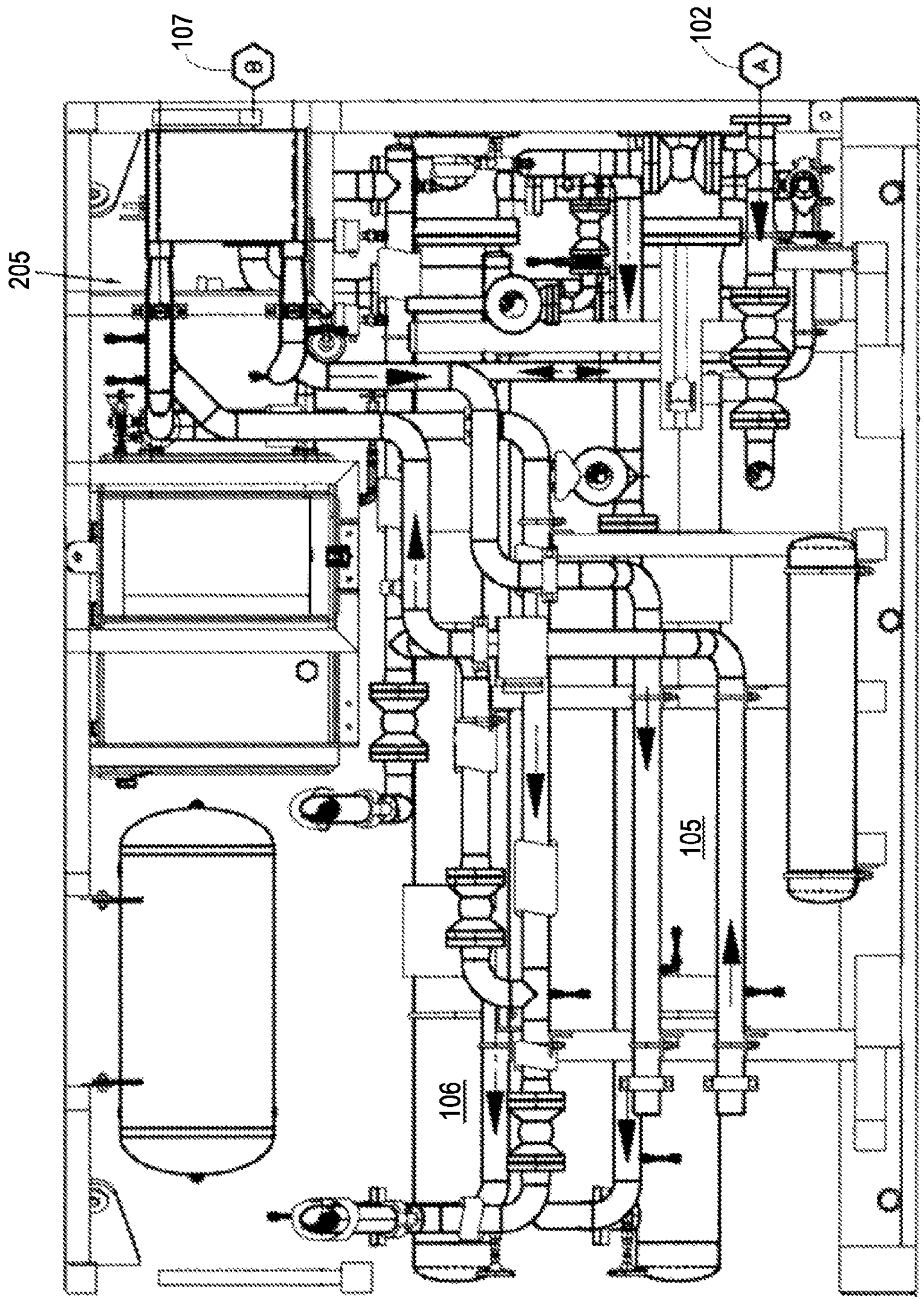


FIG. 6

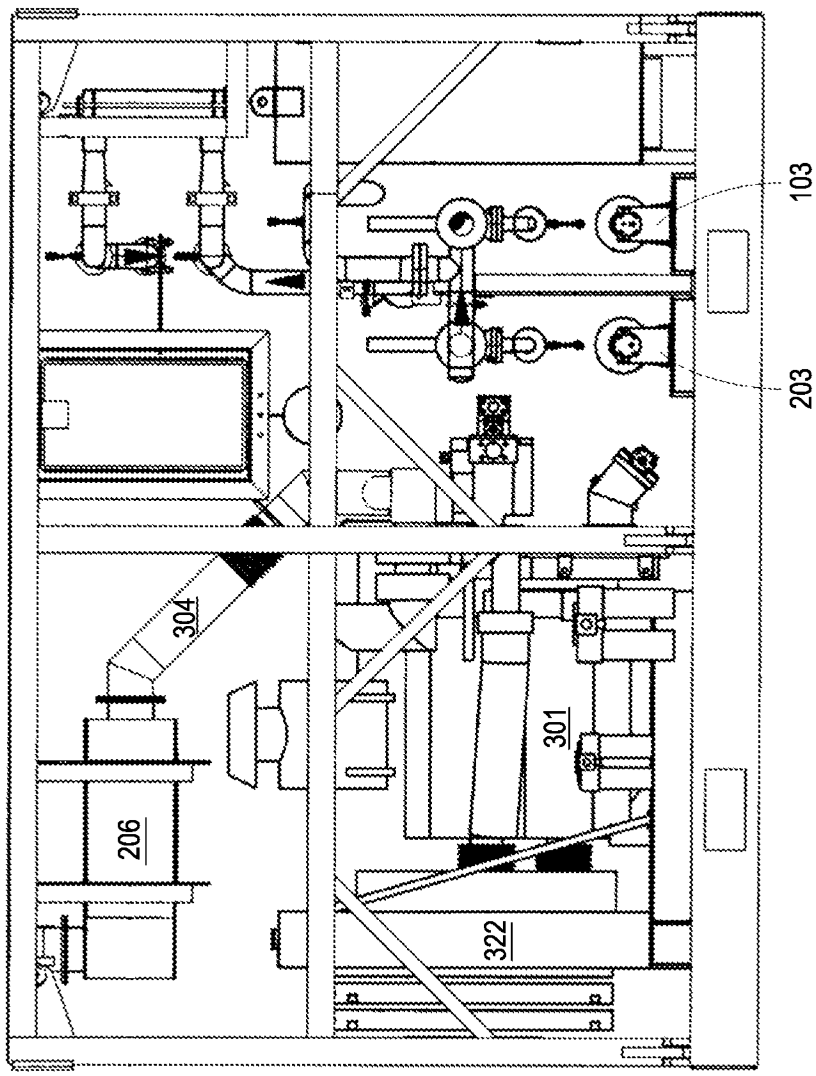


FIG. 7

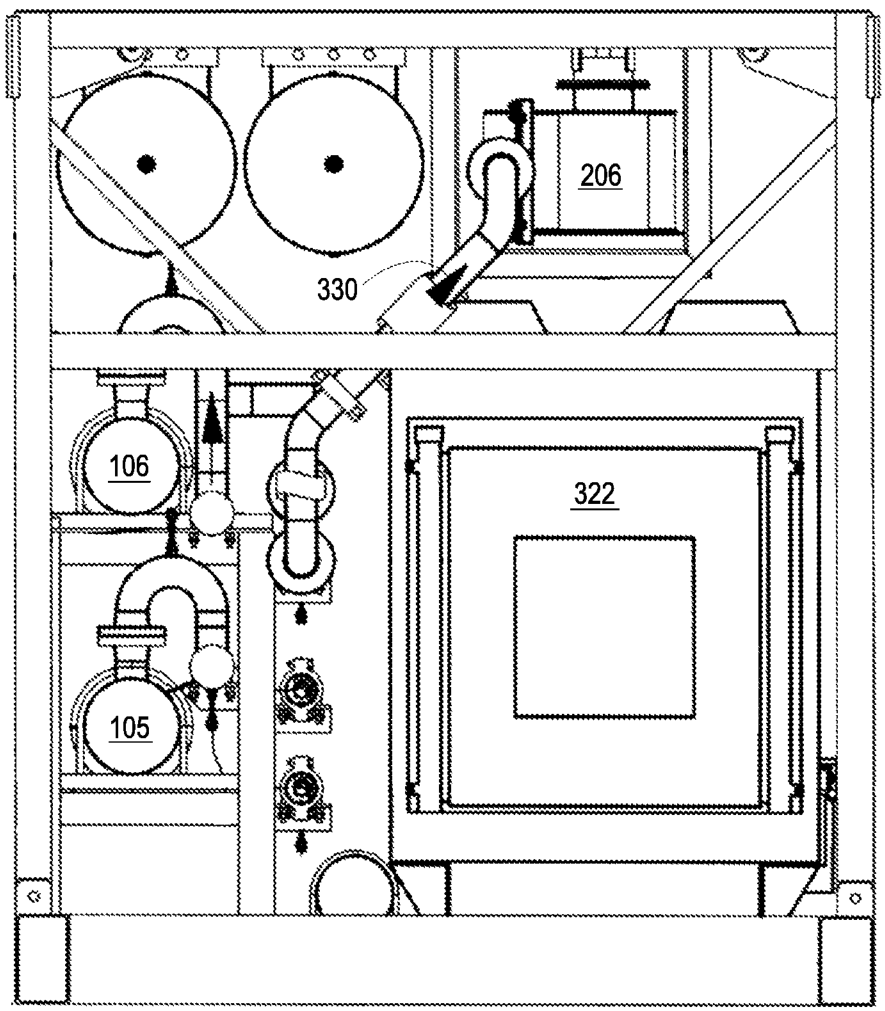


FIG. 8

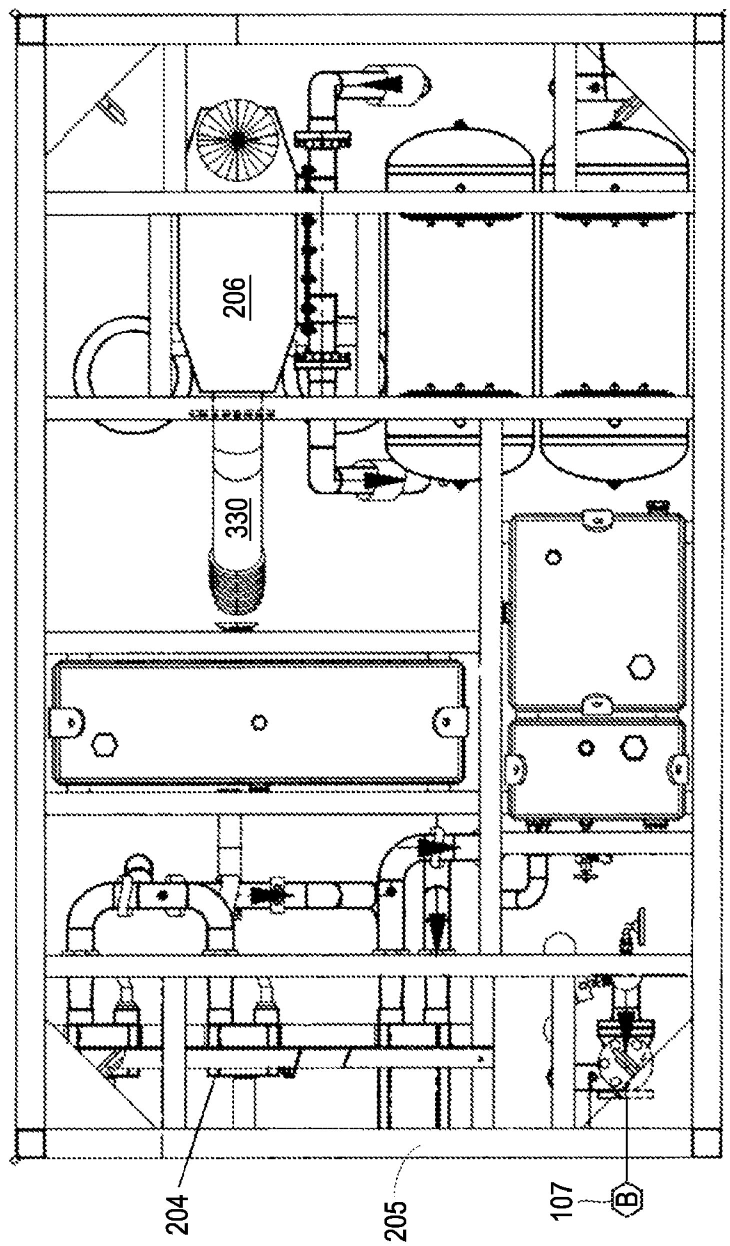


FIG. 9

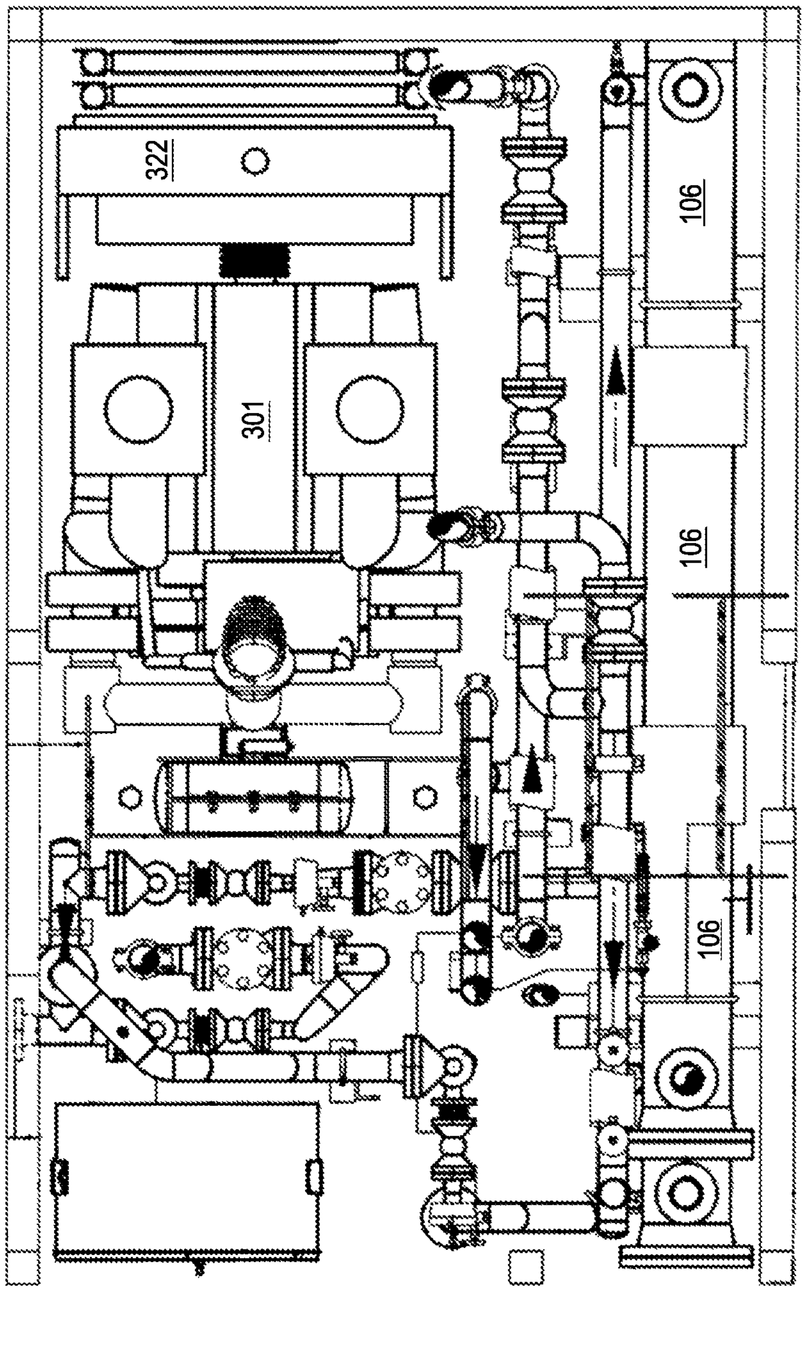


FIG. 10

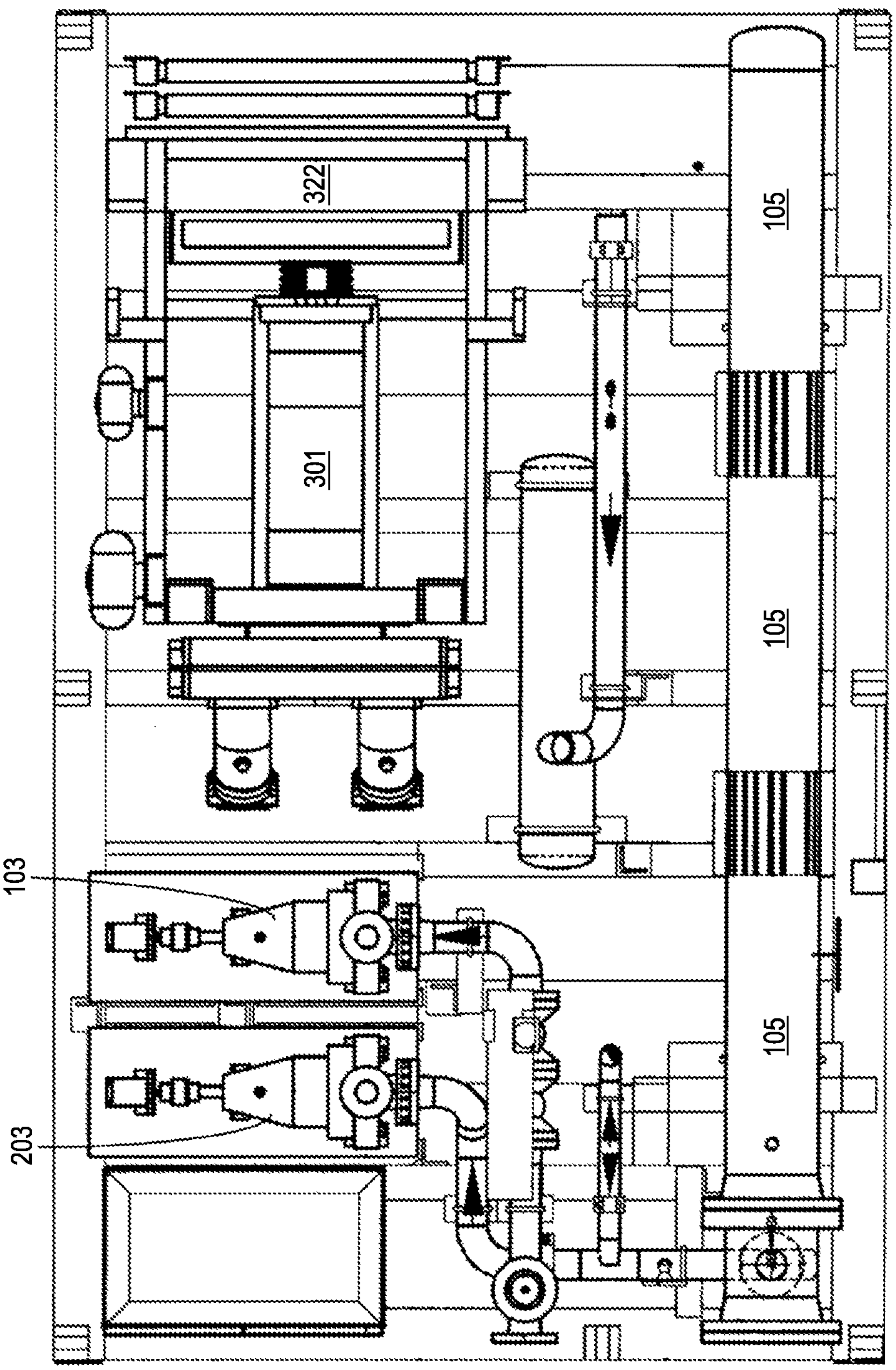


FIG. 11

PRODUCED FLUID HEATING AND SEPARATION

CROSS-REFERENCE TO RELATED APPLICATION

This application is a divisional of application Ser. No. 13/424,937, filed Mar. 20, 2012, which claims the benefit under 35 U.S.C. §119(e) of U.S. Provisional Patent Application No. 61/473,433, filed Apr. 8, 2011, both of which applications are hereby incorporated by reference.

FIELD OF DISCLOSURE

The present invention is directed to an apparatus and method for efficiently and safely heating produced fluids, e.g., comprising hydrocarbons and water, using a heat transfer system that separates the direct-heat from an engine from the hydrocarbons in the produced fluid. More particularly, work and heat from the engine is directed into heat exchangers where it heats a heat transfer fluid, that transfers heat to a produced fluid heat exchanger, which heats the produced fluids, e.g., so that hydrocarbons can be separated from produced water by helping break a hydrocarbon/water emulsion. In a preferred embodiment, the apparatus is a self-contained, portable unit that is able to be moved into position, operated, and then removed, for example from an offshore oil platform.

BACKGROUND

Oil and gas wells are drilled into the earth and reach a subterranean reservoir so that liquid and gaseous hydrocarbons can be recovered from the reservoir. Eventually, the gas and liquid hydrocarbons are separated into various fractions for use as gasoline, petrochemicals, asphalt, waxes, and the like, at a refinery.

A number of patents disclose the use of a diesel engine to heat a chemical solution before injecting the chemical solution into a well bore and for injecting engine heat into the well bore for improving the recovery of hydrocarbons from the well, e.g., see U.S. Pat. Nos. 6,073,695 and 3,833,059.

Produced fluids are water based fluids recovered from a oil or gas well, and are often contaminated with hydrocarbons. The hydrocarbons prevent direct disposal of the produced fluids. Therefore, separators are often installed in attempts to reduce the hydrocarbon content in the produced fluid.

The hydrocarbon content of the produced fluid includes highly combustible materials, for example, C_6-C_{10} hydrocarbons, C_{10}-C_{20} hydrocarbons and C_{20}-C_{28} hydrocarbons.

The apparatus and method described herein are directed toward heating the produced fluid after removal from the well. The heating can be one step in the separation of contaminants, e.g., particulates, or hydrocarbons, from the produced fluid.

SUMMARY

The apparatus and methods described herein improve the on-site separation of hydrocarbons from the produced fluids of a well bore by efficiently and safely separating the direct-heat from an engine and the hydrocarbons in the produced fluids while significantly increasing the temperature of the produced fluids. Energy (heat) from the engine is exchanged with a non-combustible heat transfer fluid that then transfers heat to the produced fluids. In one embodiment, the apparatus operates at the well site, e.g., an offshore oil platform.

It should be noted that direct heat transfer between the diesel engine gas exhaust and/or water exhaust does not occur in the apparatus and methods described herein. It has been found that a primary heat transfer step between the diesel engine gas exhaust and/or water exhaust must occur with a heat transfer fluid in order to properly control the temperature of the recovered hydrocarbons in order to avoid hydrocarbons flashing and potential explosions. The apparatus and methods described herein utilize only the heat produced by a diesel engine for heating and separating the recovered hydrocarbons.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

FIG. **1** is a process flow schematic of the embodiment of the present disclosure presented in FIGS. **2-11**;

FIG. **2** is a perspective view of one embodiment of the present disclosure;

FIG. **3** is a perspective view of one embodiment of the present disclosure;

FIG. **4** is an internal view of one embodiment of the present disclosure wherein multiple features have been removed to show internal structure;

FIG. **5** is an internal cross-sectional view of a first end of the embodiment shown in FIGS. **2** and **3**;

FIG. **6** is an internal cross-sectional view of a first side of the embodiment shown in FIGS. **2** and **3**;

FIG. **7** is an internal cross-sectional view of a second side of the embodiment shown in FIGS. **2** and **3**;

FIG. **8** is an internal cross-sectional view of a second end of the embodiment shown in FIGS. **2** and **3**;

FIG. **9** is a top-down view (upper piping plan) of one embodiment of the present disclosure;

FIG. **10** is an internal top-down cross-sectional view (intermediate piping plan) of the embodiment shown in FIG. **9**; and

FIG. **11** is an internal top-down cross-sectional view (lower piping plan) of the embodiment shown in FIG. **9**.

DETAILED DESCRIPTION

The apparatus and methods described herein may be understood more readily by reference to the following detailed description and the figures provided. It is to be understood that this invention is not limited to the specific components, articles, processes and/or conditions described, as these may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting.

In one embodiment, the apparatus and methods described herein are adaptable for placement and use on an offshore oil platform. For example, the apparatus can be sufficiently self-contained such that the apparatus can be transferred from a first location (e.g., a onshore storage site) to the offshore oil platform. The transfer can be, for example, by a watercraft or aircraft. Importantly, the apparatus conforms to the safety requirements common on offshore oil platforms, these include but are not limited to no open flame and non-sparking. In offshore oil platform use, the method can include those features provided below as well as, transporting the apparatus to the oil platform, attaching the apparatus to a produced fluid source, attaching the apparatus to a treated water output conduit, treating as a batch-process the produced fluid from an oil or gas well, or removing the apparatus from the oil platform.

As described herein, the separation of hydrocarbon contaminants and water is facilitated by raising the temperature of the hydrocarbon contaminated water. Herein, in one embodiment, is an apparatus, a produced fluid heating apparatus, for heating the produced fluid from a gas or oil well. Produced fluids includes the produced water from the well. Produced water includes the completion fluids used during the drilling, workover, and completion of a well. The produced water can be understood to include, for example, hydrocarbon contaminated water received directly from the well, water received from a production facility, or water received from a storage container. The separation of the hydrocarbons from the produced water yields processed water that contained a lower hydrocarbon concentration or content.

With reference to FIGS. **1** to **11** various embodiments of the present disclosure are herein presented. FIG. **1** is a schematic representation of the flow pathways, heat exchangers, pumps, engine, and conduits of the present disclosure. FIGS. **2** to **11** are various perspectives and representations of an apparatus that conforms to the present disclosure. Scale and distances are presented in some figures, these are presented as one embodiment of the present disclosure.

The produced fluid heating apparatus **100** includes a produced fluid pathway **101** through which the produced fluid can flow. The produced fluid pathway includes a produced fluid inlet **102**, a produced fluid pump **103**, a produced fluid pump by-pass **104**, at least one (a first) produced fluid heat exchanger **105**, and a produced fluid outlet **107**. In one embodiment, the produced fluid pathway includes a plurality of produced fluid heat exchangers, for example the pathway can include a second produced fluid heat exchanger **106**.

The produced fluid heating apparatus **100** further includes a heat generation system **300** that provides the thermal energy for heating the produced water. The heat generation system **300** can include a diesel engine **301**, a heated hydraulic fluid pathway **302**, and an engine coolant pathway **303**. In one embodiment, the heat generation system **300** includes an engine exhaust pathway **304**.

The heated hydraulic fluid pathway **302** provides a recirculating loop through which hydraulic fluid can flow. The heated hydraulic fluid pathway **302** can include a hydraulic pump **310**, a hydraulic heat delivery conduit **311**, the hydraulic heat exchanger **204**, and a hydraulic return conduit **312**. The heat generation system can further include a plurality of heated hydraulic fluid pathways **302**, for example, the system can include two heated hydraulic fluid pathways **302**. In one embodiment, the heated hydraulic fluid pathway **302** can include a plurality of hydraulic heat exchangers **204**. In one embodiment, the hydraulic heat exchanger(s) **204** is a plate and frame heat exchanger.

The engine coolant pathway **303** provides a recirculating loop through which engine coolant can flow. The engine coolant pathway **303** can include an engine heat delivery conduit **320**, an engine coolant heat exchanger **205**, and an engine coolant return conduit **321**. In one embodiment, the engine coolant pathway includes a radiator **322**. In another embodiment, the engine coolant pathway includes a radiator by-pass **323**. Typically, the diesel engine **301** includes a water pump that provides the flow for the engine coolant but a water pump external to the diesel engine **301** can be included. In one embodiment, the engine coolant heat exchanger **205** is a plate and frame heat exchanger.

The engine exhaust pathway **304** is the flow path through which the combustion exhaust flows. The engine exhaust pathway **304** can include an engine exhaust conduit **330** and an engine exhaust heat exchanger **206**. In one embodiment, the engine exhaust heat exchanger **206** is a coil type heat exchanger. In another embodiment, the engine exhaust pathway **304** includes a muffler and, optionally, a spark arrestor.

The produced fluid heating apparatus **100** further includes a heat transfer system **200** disposed between the produced fluid pathway **101** and the heat generation system **300**. The heat transfer system **200** can transfer the thermal energy from the heat generation system **300** to a produced fluid contained within the produced fluid pathway **101**. The heat transfer system **200** can include a heat transfer fluid **201** within an insulated, closed-loop heat transfer fluid pathway **202**. The heat transfer fluid preferably has a boiling point above about 100° C., for example, the heat transfer fluid can be ethylene glycol, propylene glycol, polyalkylene glycol, DOWTHERM products (DOW CORNING CORP. Midland, Mich. USA), SYLTHERM products (DOW CORNING CORP. Midland, Mich. USA), PARATHERM products (PARATHERM CORP. West Conshohocken, Pa. USA), mixtures thereof, and mixtures thereof with water. The heat transfer fluid pathway **202** provides a recirculating loop through which the heat transfer fluid **201** can flow. The heat transfer fluid pathway **202** can include a heat transfer fluid pump **203**, at least one (a first) hydraulic heat exchanger **204**, an engine coolant heat exchanger **205**, and a (first) produced fluid heat exchanger **105**.

In one embodiment, the heat transfer fluid pathway **202** includes a second produced fluid heat exchanger **106**. The second produced fluid heat exchanger **106** is disposed between and fluidly connected to, on the produced fluid pathway **101**, the first produced fluid heat exchanger **105** and the produced fluid outlet **107**. In another embodiment, the flow of the heat transfer fluid through the heat transfer fluid pathway **202** fluidly connects to the second produced fluid heat exchanger **106** then the first produced fluid heat exchanger **105**. In one embodiment, the produced fluid heat exchanger (**105** and/or **106**) can be a shell and tube heat exchanger.

In one embodiment, the heat transfer fluid pathway **202** includes a plurality of hydraulic heat exchangers **204**. For example, a first and a second hydraulic heat exchanger **204** can be arranged in-line or in-parallel along the heat transfer fluid pathway **202**.

In an embodiment that includes the engine exhaust heat exchanger **306**, the heat transfer fluid pathway **202** can includes an engine exhaust heat exchanger by-pass **331**.

In another embodiment, the apparatus described herein can be used to heat produced water to a temperature sufficient for separation of contaminants from the water. Typically, the temperature of the (supplied) produced water can be increased by 20° C. to 60° C., 30° C. to 50° C., 30° C., 35° C., 40° C., 45° C., or 50° C. For example, the temperature of the produced water can be increased to 40, 45, 50, 55, 60, 65, 70, 75, or 80° C.

In one embodiment, a method of separating hydrocarbons from water and providing processed water that comprises a hydrocarbon content less than 50 ppm, 40 ppm, 30 ppm, or 29 ppm includes treating produced water that has a hydrocarbon content greater than 100 ppm, 150 ppm, 200 ppm, 250 ppm, 300 ppm, or 350 ppm with the produced fluid heating apparatus **100** described herein. This method can include providing the produced fluid heating apparatus **100** (e.g., the diesel engine **301**, the produced fluid pathway **101**, the heated hydraulic fluid pathway **302**, the engine coolant pathway, **303**, the engine exhaust pathway **304**, and the heat transfer fluid pathway **202**) and produced water that has a hydrocarbon content greater than 100 ppm and a temperature less than about 50° C. Then channeling the produced water (e.g., from a well bore, a production facility, or a storage tank) to the first produced fluid heat exchanger **105** and through the produced fluid outlet **107** to a water treatment apparatus. Herein, channeling means conducting a flow within a pipe or similar conduit. The method can further include heating the first produced fluid heat exchanger **105** to a temperature in the range of 50° C. to 100° C. with a heat transfer fluid **201**; circulating the heat transfer fluid **201** in the heat transfer fluid pathway **202** as described herein. The method can further include circulating hydraulic fluid through the heated hydraulic fluid pathway **302** as described herein. The method can further include circulating engine coolant through an engine coolant pathway **303** as described herein.

In one embodiment, the produced water is supplied at a rate of at least 40, 50, 60 70, or 80 gallons per minute.

In an embodiment, the method can include channeling the produced water from the first produced fluid heat exchanger **105** to a second produced fluid heat exchanger **106** then through the produced fluid outlet **107** to the water treatment apparatus. The second produced fluid heat exchanger **106** can be heated to a temperature in the range of 50° C. to 100° C. with the heat transfer fluid **201**.

In an embodiment, the heat transfer fluid pathway **302** comprises a second hydraulic heat exchanger **204**. The first and the second hydraulic heat exchangers **204** can be arranged in-line or in-parallel along the heat transfer fluid pathway **202**.

In another embodiment, the produced fluid outlet **107** is fluidly connected to a water treatment apparatus. The water treatment apparatus is a means for separating hydrocarbons from water. The water treatment apparatus can be selected from an API oil-water separators, a centrifugal oil-water separator, a weir box, a surge tank, a pressurized or an atmospheric separator, a filtering vessel, a polishing vessel, or any vessel that will provide sufficient residence time for the separation of a non-emulsified hydrocarbon/water combination. Herein, the water treatment apparatus can be an apparatus as described in the following co-owned U.S. Pat. Nos. 7,297,279; 6,749,757; 6,409,924; 6,398,966; 6,398,951; 6,358,422; 6,235,201; 5,935,444; 5,922,206; 5,670,435; 5,567,318, each incorporated herein by reference in their entirety. In one embodiment, the water treatment apparatus can include a Hi-Flow Oil Removal System (AMCOL Int'l), and/or a CRUDESORB system, containing an organophilic clay (CETCO Oilfield Services), as disclosed in one or more of the above referenced U.S. patents.

In the methods and apparatus described herein, the diesel engine can drive the heat transfer fluid pump, for example, by providing a hydraulic flow by way of a hydraulic pump to the heat transfer fluid pump. The heat transfer fluid pump can be for example, a hydraulic driven centrifugal pump (ACE PUMP Corp., Memphis Tenn.).

In an embodiment, the heat transfer fluid pathway **202** can include an engine exhaust heat exchanger **206** and a by-pass to the engine exhaust heat exchanger **331**. The method can then include conducting engine exhaust through an engine exhaust pathway **304** that includes an engine exhaust conduit **330** and the engine exhaust heat exchanger **206**.

The foregoing written description provides examples of structure and function representative of the present invention, but not intended to limit the scope beyond that which is recited in the appending claims.

What is claimed:

1. A method of reducing hydrocarbon content in produced water to less than 50 ppm comprising:

providing a diesel engine;

providing produced water that has a hydrocarbon content greater than 100 ppm and a temperature less than about 50° C.;

channeling the produced water to a first produced fluid heat exchanger; heating the first produced fluid heat exchanger to a temperature in the range of 50° C. to 100° C. with a heat transfer fluid;

circulating the heat transfer fluid within a heat transfer fluid pathway that includes a heat transfer fluid pump, a first hydraulic heat exchanger, an engine coolant heat exchanger, and the first produced fluid heat exchanger;

circulating hydraulic fluid through a heated hydraulic fluid pathway that includes a hydraulic pump, a hydraulic heat delivery conduit, the first hydraulic heat exchanger, and a hydraulic return conduit;

circulating engine coolant through an engine coolant pathway that includes the diesel engine, an engine heat delivery conduit, the engine coolant heat exchanger, an engine coolant return conduit, and a radiator to the diesel engine; and

channeling the produced water from the first produced fluid heat exchanger to a water treatment apparatus to separate hydrocarbons from the produced water such that processed water has a hydrocarbon content less than 50 ppm.

2. The method of claim **1**, wherein the produced water is provided at a rate of at least 50 gallons per minute.

3. The method of claim **1** further comprising

channeling the produced water from the first produced fluid heat exchanger to a second produced fluid heat exchanger;

channeling the produced water from the second produced fluid heat exchanger to the water treatment apparatus; and

heating the second produced fluid heat exchanger to a temperature in the range of 50° C. to 100° C. with the heat transfer fluid.

4. The method of claim **1**, wherein the heat transfer fluid pathway comprises a second hydraulic heat exchanger.

5. The method of claim **4**, wherein the heat transfer pathway comprises the first and the second hydraulic heat exchangers in parallel.

6. The method of claim **1**, wherein the heat transfer fluid pump is driven by a hydraulic flow provided by the diesel engine.

7. The method of claim **1**, wherein the hydraulic pump is driven by the diesel engine.

8. The method of claim **1**, wherein the heat transfer fluid pathway further includes an engine exhaust heat exchanger and a by-pass to the engine exhaust heat exchanger.

9. The method of claim **8** further comprising

conducting engine exhaust through an engine exhaust pathway that includes an engine exhaust conduit and the engine exhaust heat exchanger for heating the heat transfer fluid with said engine exhaust.

* * * * *